

CARDIOVASCULAR DYNAMICS: IMAGE-BASED MODELING OF AORTIC BIOMECHANICS FROM NANO- TO MACRO-SCALES

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Biomechanical factors are important in maintaining normal vessel structure and can also impact congenital (coarctation) and acquired (atherosclerotic, hypertensive, aneurysmal) diseases. The goals of the project are fourfold. First we are utilizing 4D MRI analysis methods to characterize hemodynamic conditions and wall motion of the human thoracic and abdominal aorta. Second, we are constructing a 3D microstructural computational model of the medial lamellar unit (MLU), the building block of large blood vessels, using image-based modeling methods applied to confocal microscopy (microscale resolution) and serial block face scanning electron microscopy (SBFSEM) data (nanoscale resolution). Third, we will develop and apply homogenization methods to obtain equivalent macroscale properties for our image-based microarchitectural model. Fourth, we will model blood flow and vessel wall deformation in normal subjects and patients with congenital and acquired diseases of the aorta. We have made progress in aims 1,2, and 4 and will commence work on aim 3 in the coming year.

Figure 1a shows the application of our methods to quantify vessel wall motion from 3D, time-resolved (4D) MRI data. These methods and data will be essential for assigning vessel wall properties in our 3D, fluid-solid interaction methods (Figure 1c). At present, tissue constitutive equations are purely phenomenological in nature. The data and models we are developing will enable the creation of new, vessel wall constitutive equations that reflect the microstructure of blood vessels in health and disease. Figure 1b depicts new data (and a new discovery) related to the presence of interlamellar elastin fibres that connect elastin sheets in the aortic wall. We will investigate the importance of these fibers in maintaining the structural intensity of blood vessels.

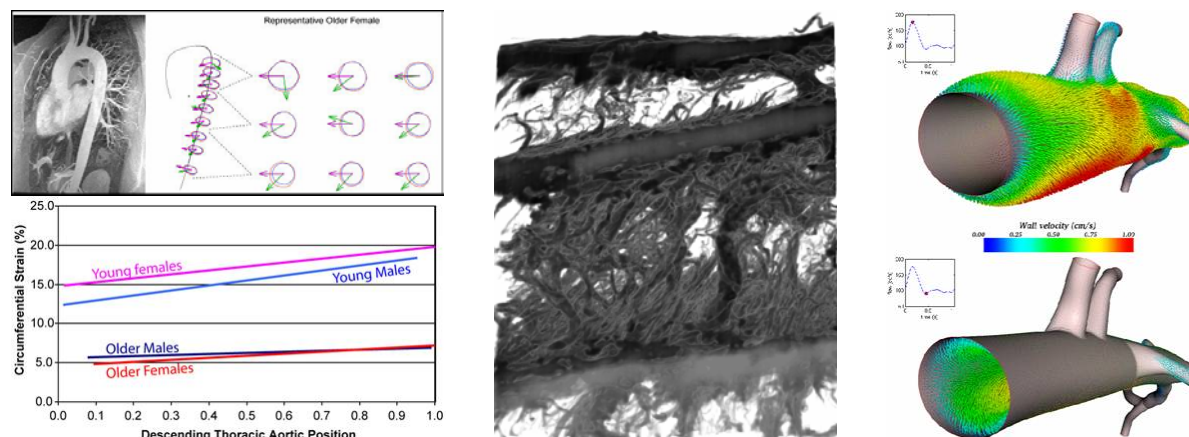


Figure 1. Multiscale, image-based modeling of aortic biomechanics, (a) aortic wall motion for representative older female subject and strain vs. aortic position for all subjects (b) SBFSEM data showing interlamellar elastin fibres connecting adjacent elastin sheets in rat aorta, (c) vessel wall velocity vectors at two points of the cardiac cycle: peak systole (top) and early diastole (bottom).

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